THE ROLE OF STREAMS IN THE DEVELOPMENT OF THE GREAT SAND DUNES AND THEIR CONNECTION WITH THE HYDROLOGIC CYCLE

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The Great Sand Dunes National Monument is home to a 39 square mile dune field whose complexity belies its relatively small size. The complexity manifests itself as diverse dune development resulting from the interaction of wind and water, and the nature in which their flow is controlled by the local mountain front. The bimodal to complex winds are responsible for creating the dunes, while the streams influence the features of the dune field. Because of the importance of the streams in maintaining the dune system, aspects of the hydrologic cycle at the Great Sand Dunes National Monument Area are studied and monitored to learn how to relate climatic conditions to stream flows and the state of the dune field.

THE ROLE OF STREAMS IN DUNE FIELD DEVELOPMENT

There are two streams that flow along segments of the dune field perimeter. Medano Creek flows along the east and southeastern sides of the dune field and Sand Creek flows along the northwestern side, (see Figure 2). Both completely infiltrate into the ground water system, although Sand Creek occasionally reaches some playa lakes located 10 miles from the mountain front. Discharge has been measured on each stream since 1992 with Parshall flumes placed near where the streams enter monument property. Sand Creek is the larger of the two. Its peak flow has ranged from 54 to 225 cubic feet per second (cfs) and occurs in May and June. Its base flow varies from 0 to 1 cfs. Medano Creek's peak flow has fluctuated from 9 to 65 cfs and base flows are consistently 2-3 cfs.

The streams have a give and take relationship with the dune field. They erode sand from some parts of the dune field and deposit it in others. Each exhibits a net erosion of sand from along the mountain front and deposition on the valley floor during high runoff periods. As flows decrease, the depositional areas dry up, exposing wide, braided channels so that the prevailing winds from the southwest can blow the sand back into the dune field. This results in the dune field having a crescent shape and the thickest sand deposits (up to 750 feet in relief) occurring down wind from the creeks (see figure 1). Each lobe of the crescent is an accumulation of the sand supplied by the streams and the great thickness comes from vertical dune growth allowed by the excess sand and multiple wind directions. Medano Creek is smaller than Sand Creek, but it builds a larger lobe because its erosional section has a longer contact with the dune field.

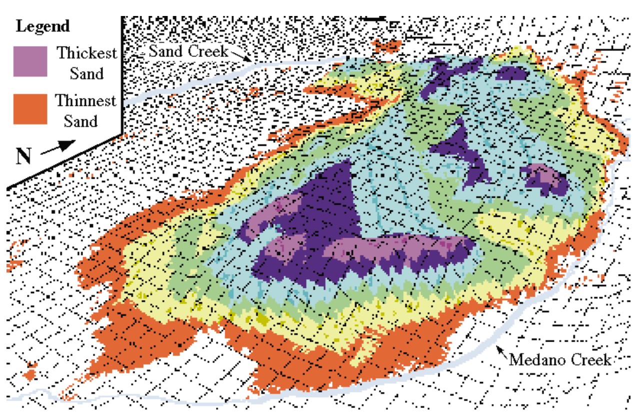

Figure 1. Sand thickness above the San Luis Valley plain. Created by the GIS division of the Rocky Mountain Regional Office, National Park Service.

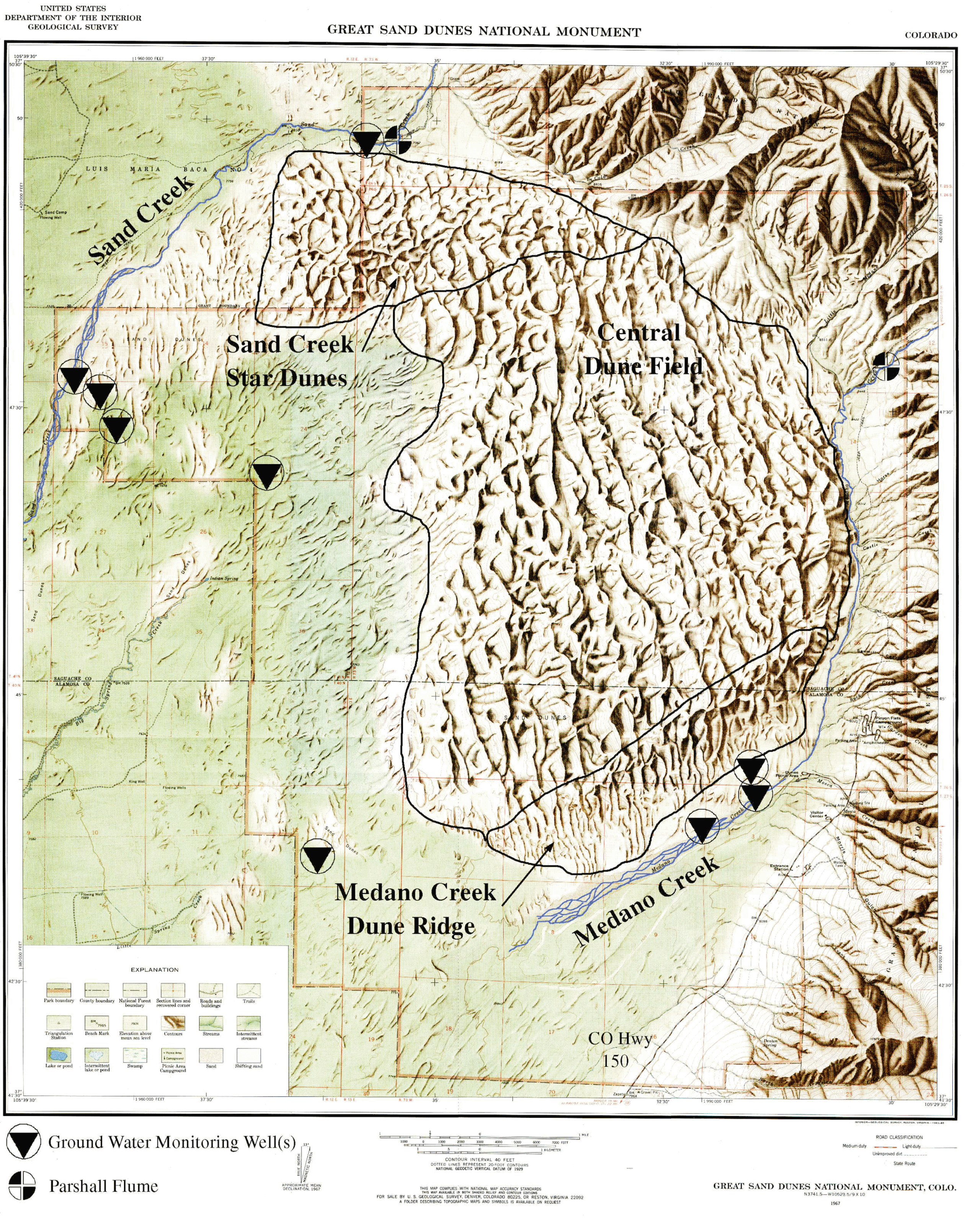

Figure 2. Location of Medano and Sand Creeks, monitoring wells, and Parshall flumes at the Great Sand Dunes National Monument. Modified from USGS map Great Sand Dunes National Monument, Colo.

Medano and Sand Creeks are particularly effective at transporting sand because surge flow can develop in their braided channel sections. Each surge is a pulse of water occurring in regular intervals that can potentially flush more sand down the stream than steady flow. It is a rare phenomena because it requires a high flow regime and a smooth, mobile channel. The fast flow creates bed forms called antidunes. They increase the amount of water stored in the areas where they develop by 20 percent, since they force the water to flow over a sinuous surface instead of a flat surface. The antidunes are not stable and eventually break, releasing the stored water. Since the channel is sandy and creates little turbulence, the pulse of water produced by the collapse of the antidune continues downstream in a discrete packet and picks up more water from other antidune fields (Bean, 1977; Schumm et al., 1982). Surge flow develops better on Medano Creek because its braided channel segment is steeper.

The magnitude of the surge waves depends on water depth. When flows are at the upper discharge levels, the surge wave can be up to one foot high and have a period of 90 seconds. At lower flows, the waves are only a few inches high and have periods less than one minute. In areas where only a thin sheet of water is flowing, several tiny pulses can form in a second.

The action of the creeks contribute to two of three distinct regions of dune development, see figure 2 (Valdez, 1992). The area along Medano Creek is known as the Medano Creek ridge. The thick sand deposits and closely spaced reversing dunes are a direct response to the availability of sand supplied by Medano Creek. Even the close spacing and aggregational nature of the north trending dunes cannot hold all the sand supplied to them, so a second northeast trending ridge fills their troughs and forms the horizon of the ridge. This gives the area an appearance more similar to a sand mountain range than individual dunes. The second area that shows stream affects is known as the Sand Creek star dunes. The many star dunes are the result of a complex wind regime, but a sequence of transverse dunes leading from the Sand Creek floodplain to the star dunes indicate that the source of their sand is Sand Creek. The third area, the central dune field, isn't affected by the streams and as a result displays the simplest dune formation. It has large north trending reversing dunes, with an occasional star dune, that are separated by vegetated troughs. Without the influence of the streams, the entire dune field would probably look like the central dune field and it would likely be oval shaped.

THE CONNECTION OF THE STREAMS TO THE REST OF THE HYDROLOGIC CYCLE

The importance of the streams in the dune system was first realized in the early 1990s. Since then, the National Park Service (NPS) has aspired to better understand their function. Research and monitoring by the NPS and others have laid the groundwork for the these goals to be reached. The first work was intended to explore the scope of the water resources and to start collecting baseline data. After the nature of the water systems was known, then efforts to quantify the effects of the streams and predict how they would react to changes in the local hydrologic cycle were begun.

The stimulus for all the work done since 1990 was a ground water development project proposed on a ranch adjacent to the Great Sand Dunes National Monument. It was designed to withdraw 200,000 acre-feet each year and predicted a lowering of the water table of 150 feet along the monument boundary. The potential for such a drastic change created a real need to understand the relationship between the ground water and the dune field and other natural resources and to predict if those changes were a threat to the goals of the NPS.

The initial projects were intended to determine where the sand moisture within the dunes came from and the type of connection between the streams and ground water. The sand moisture was extracted by flushing a sand core with distilled and deionized water. A chemical analysis of the effluent indicated that the source of the residual moisture was precipitation. Two methods were used to determine the interaction of the streams with ground water. The first was to drill 21 ground water monitoring wells throughout the park and place Parshall flumes on Sand and Medano Creeks. The second used Schlumberger soundings and resistivity testing to map the water table near the creeks. Twelve of the monitoring wells have automated gauging equipment installed while the others are periodically measured manually. The data collected thus far indicates seasonal fluctuations in the water table of up to 10 feet in shallow wells (20 feet) near the Sand and Medano Creeks and fluctuations of < 1 foot in deeper creek wells (100 feet) and wells away from the streams. Most of the wells indicate a simple, surficial aquifer, but the wells drilled into Medano Creek suggest as many as three aquifers levels are within 100 feet of the surface (Hadlock, 1995). The geophysical methods verified the effluent nature of the streams as well as noting differences in hydrologic characteristics of Sand Creek along the mountain front and out in the valley plain (Harmon et al, 1992). It also found areas were Sand Creek was seasonally influent. Both studies predicted that any significant lowering of the water table would increase the gradient between the streams and ground water and decrease the extent and volume of flow, the ability for surge flow to develop, and the ability of these streams to transport sand. With this information in hand, the NPS and other agencies filed an opposition to the water development project and defeated it in water court.

The current research seeks to quantify the role of Medano Creek and predict its effects based on measuring other parameters of the hydrologic cycle. Twenty four survey stations are located every 1,000 feet along the length of Medano Creek's braided channel. Each year, before spring runoff and after the creek has receded, a stream bed profile is surveyed. Changes in the profile are used to calculate the volume of sand moved by the creek during its runoff period and by the wind when the channel is dry. After the first year of the study, the erosion-deposition boundary was found to be 1,000 feet upstream from the dunes parking lot. An average of two feet of sand accumulated in the channel downstream of the parking lot which represents 2 x 107 cubic feet of sand deposited by a flow of 8,500 acre-feet. This project will continue at least two more years to define any exponential changes that may occur with differing runoff levels.

The parts of the hydrologic cycle of interest to the NPS are how the snowpack, storm runoffs, and the position of the water table relate to stream flow rates and duration. A Snotel site was installed near the headwaters of Medano Creek in
October of 1995. It measures the water content of the snowpack and precipitation. Although it will take several years to define statistical parameters, its data will be directly compared to runoff characteristics. When combined with information about how the creek is advancing and receding, changes in the water table, and stream discharge, then a better understanding of the hydrologic cycle will exist.

The quest to understand the role of streams in the maintenance of the dune field and how it could be affected by changes in the hydrologic cycle is a work in progress. Hydrologic conditions vary yearly and climatic trends change, therefore all the hydrologic measurement are setup as monitoring projects that operate on an ongoing manner.

The cycle is actually quit simple. It is evident that the snow in the mountains melts, flows down the streams, carries sand, and soaks into the ground (minus the evapotranspiration component). Predicting what changes in any part of the cycle would do to the other parts is not so simple.

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